

Sensitivity of tropical tropospheric composition to lightning-  
NO production and ENSO

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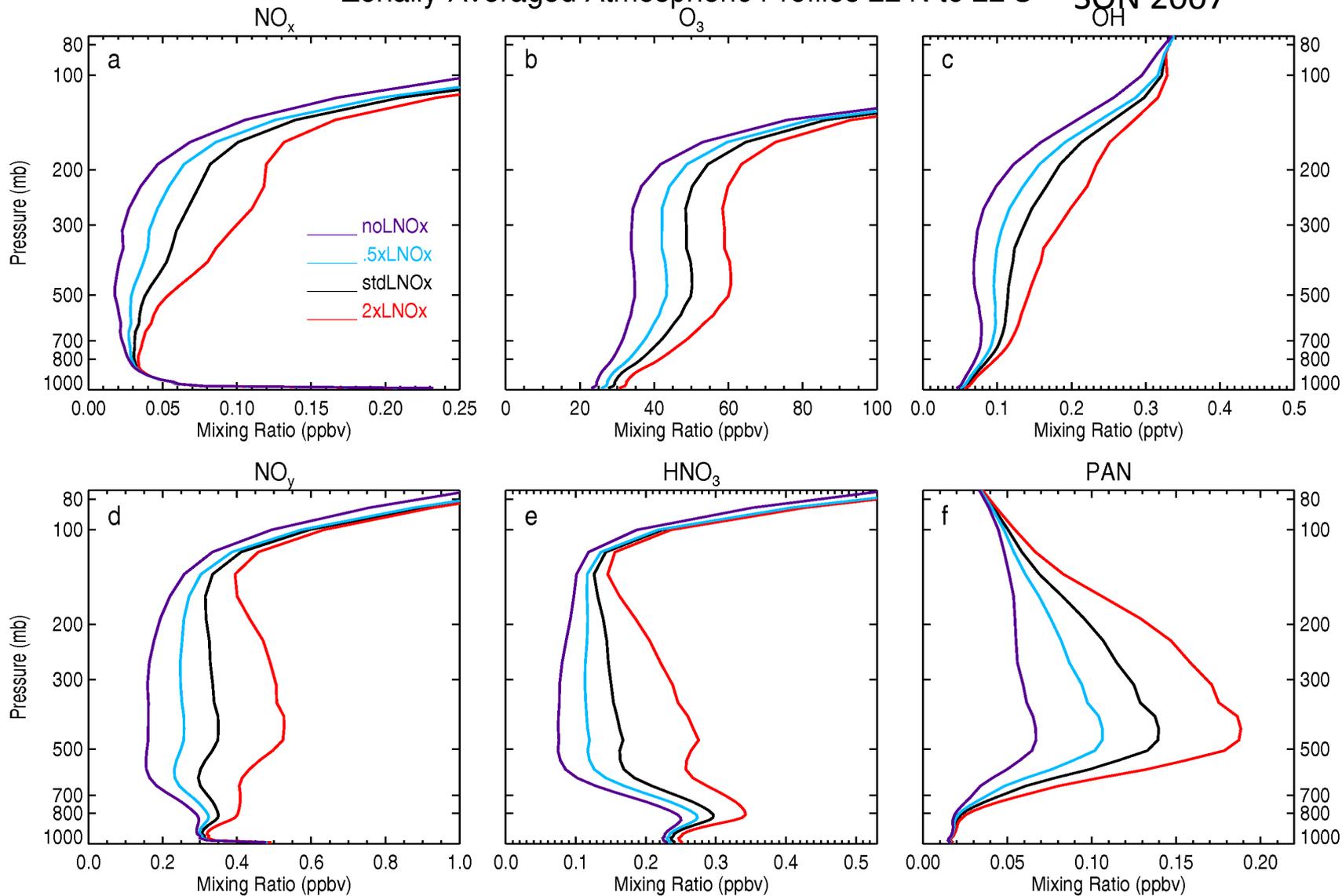
# Outline

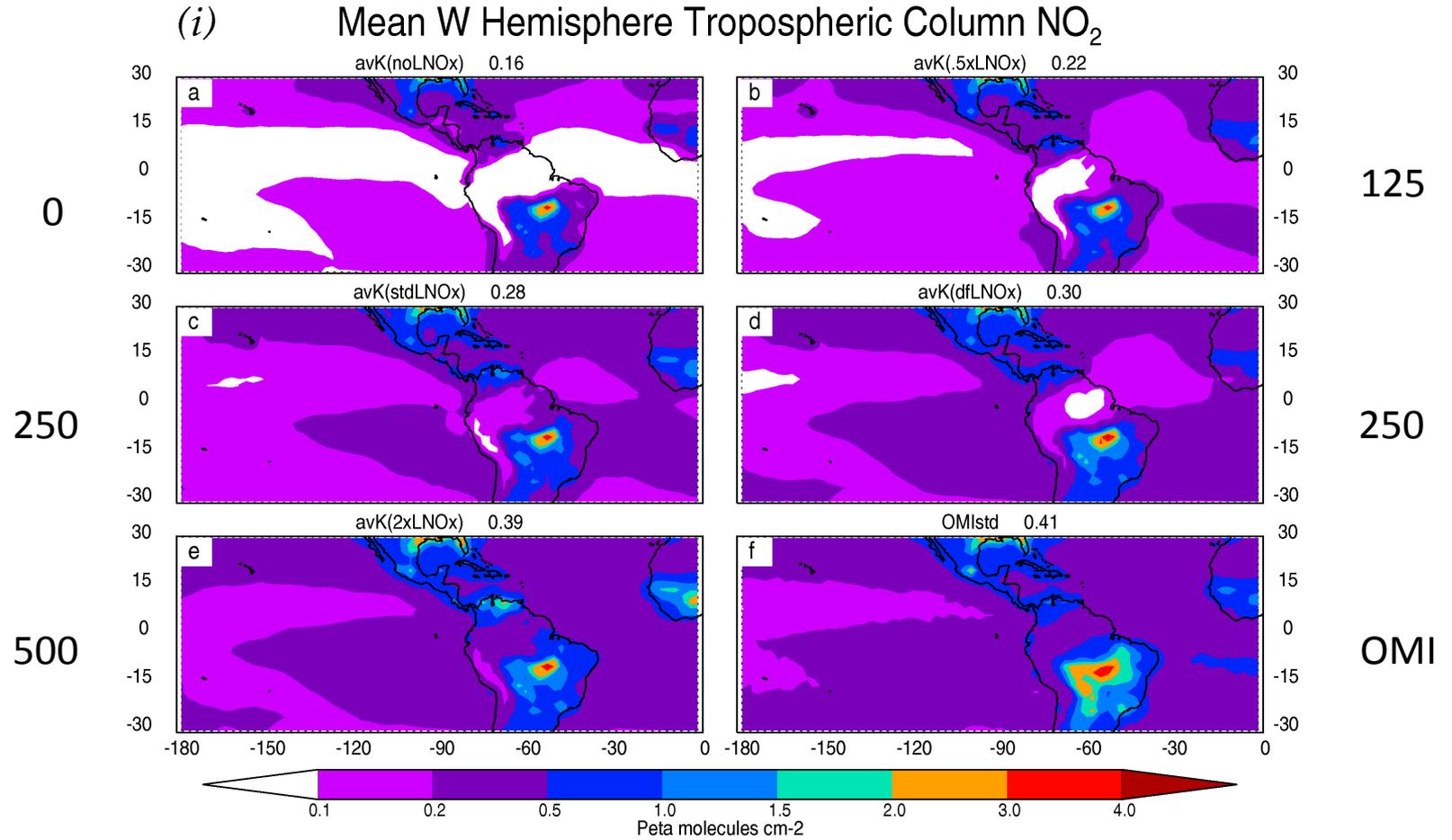
- Model NO<sub>2</sub> and O<sub>3</sub> are compared to OMI and TES for lightning-NO sources of 0, 2.5, 5, and 10 N / yr during the Sep-Nov 2007 time period (C. Liaskos, in prep, 2014)
- Radiative flux due to ozone attributable to lightning is shown
- El Nino (2006) – La Nina (2007) differences in lower-, middle-, and upper-tropospheric CO are compared for the Oct15-Nov14 time period using MOPITT, AIRS, TES, and MLS CO products

# NASA GEOS-5 CCM

- NASA GEOS-5 CCM was run in replay mode (ozone was not replayed) utilizing MERRA reanalysis data to constrain model dynamics
- Base Run Time Period: June 2006 to March 2008 (5.0 Tg N / yr LNOx)
- Sensitivity Runs with lightning-NO sources of 0, 2.5, 5.0, and 10.0 Tg N / yr were run for Jun-Dec 2007 (Sep-Nov analyzed).
- A sensitivity run with a fixed (monthly climatology) 5.0 Tg N source of LNOx was also run for Jun-Dec 2007.
- 2.0° x 2.5° resolution with 72 vertical layers and 0.01 hPa model top
- LNOx source is assumed to be proportional to the sum of normalized integrated cold-core convective mass flux and normalized surface temperature-cubed perturbation from 273 K.
  - separate continental and marine fits
  - Each term is normalized by its five-year mean before use.

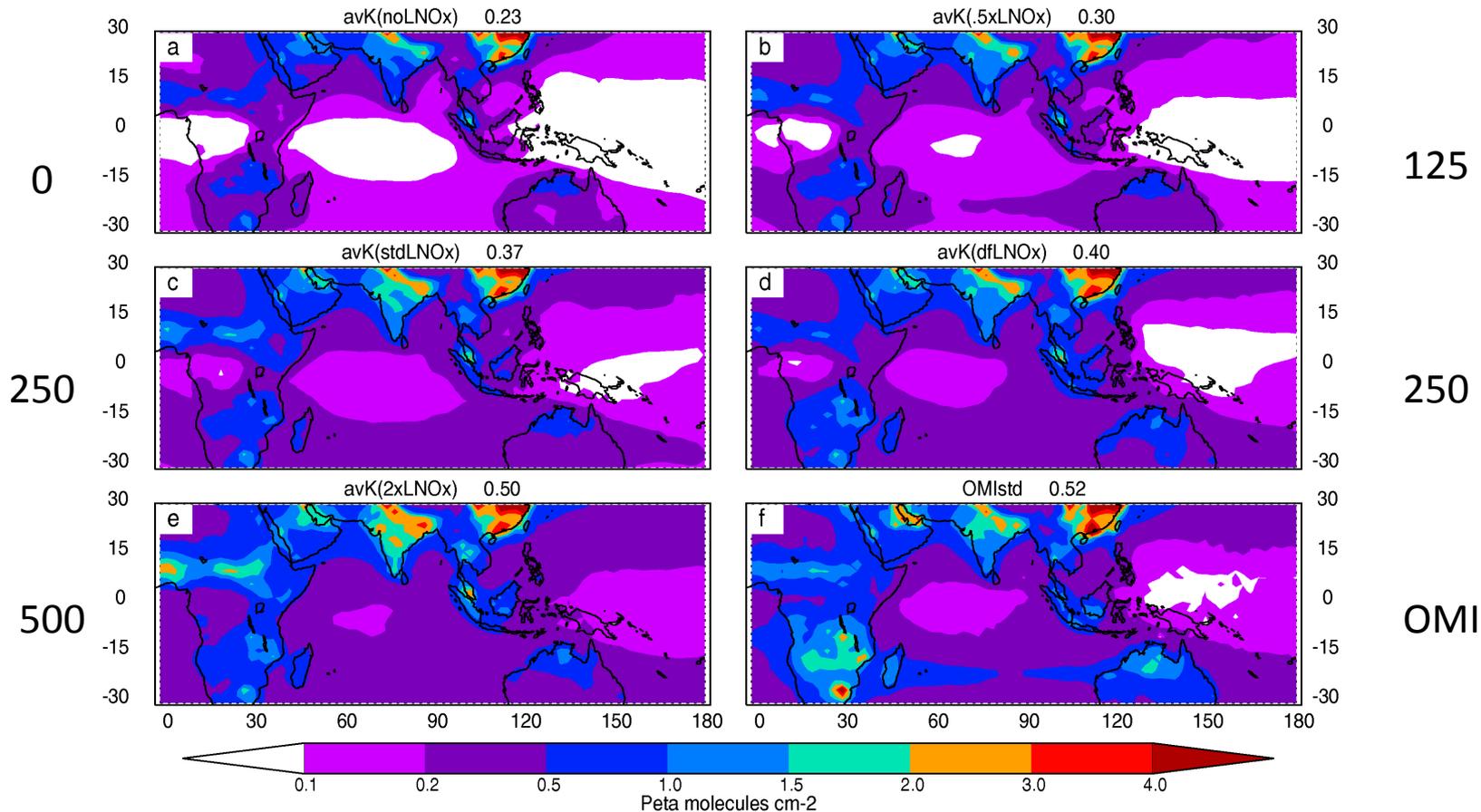
# Zonally-Averaged Atmospheric Profiles 22°N to 22°S SON 2007



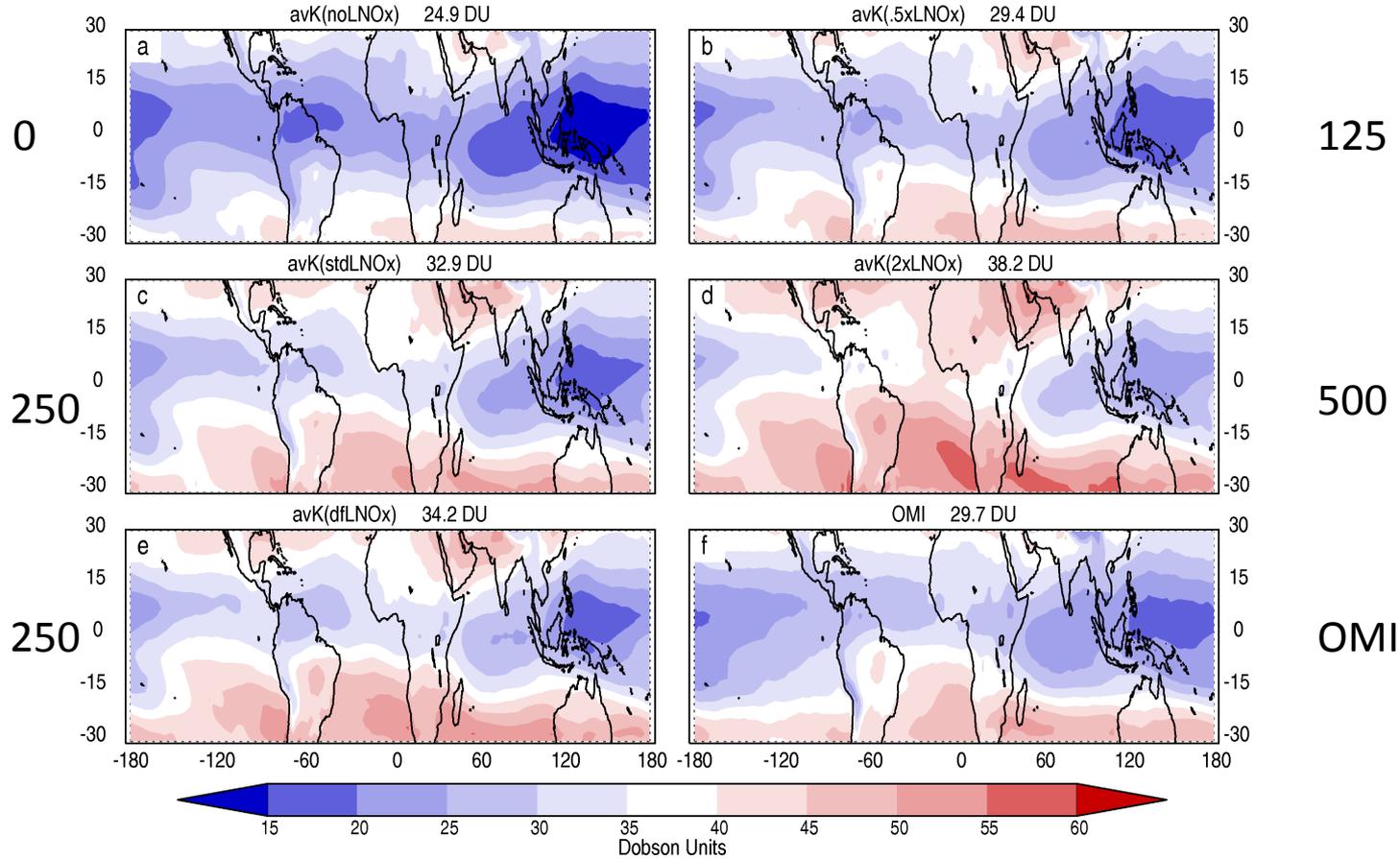


OMI NO<sub>2</sub> (Bucsela et al., 2013)

(ii) Mean E Hemisphere Tropospheric Column NO<sub>2</sub>

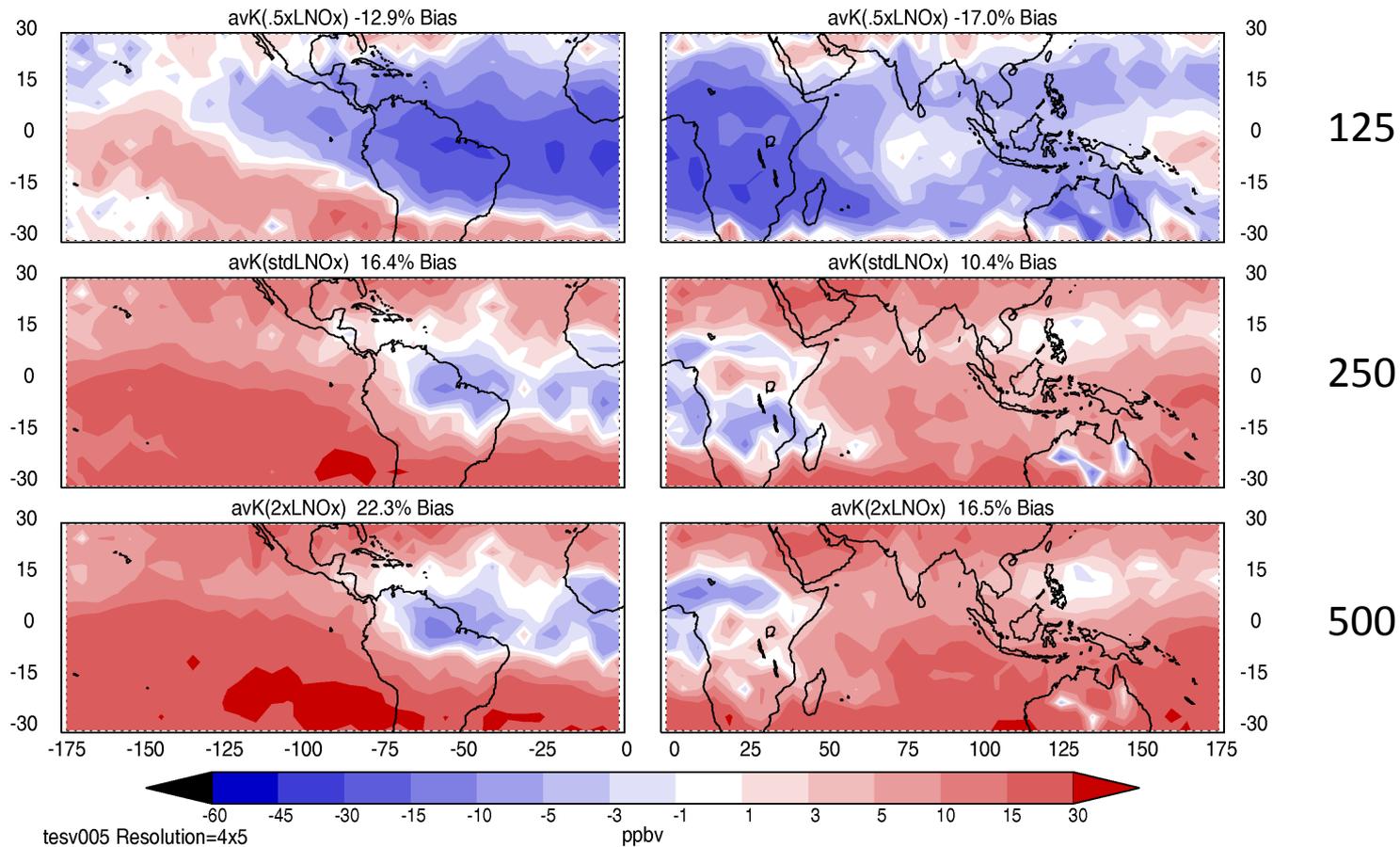


# NASA-GSFC CCM and OMI TCO



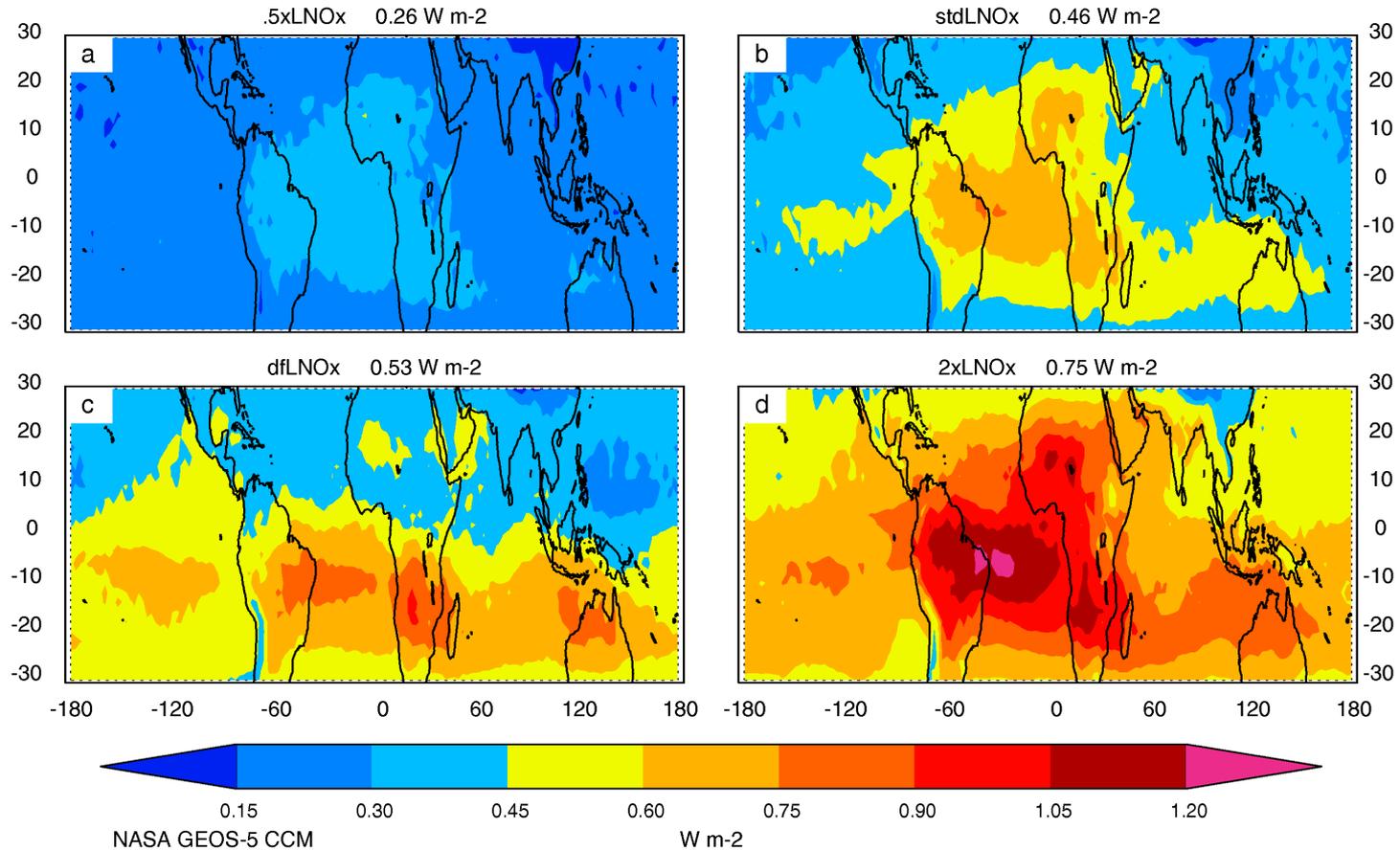
OMI TCO (Liu et al., 2010)

(i) Mean O<sub>3</sub> Bias with Respect to TES at 261 hPa



TES ozone (Herman et al., 2012)

# SON Mean Radiative Flux at 163.66 hPa



Change in 164 hPa radiative flux attributable to ozone with a LNOx source

# Conclusions

- Mean CCM 300 hPa tropical ozone equals 30, 40, 50 and 60 ppbv for LNO<sub>x</sub> sources of 0, 125, 250, and 500 moles per flash. Mean OH for the same LNO<sub>x</sub> sources equals 0.07, 0.10, 0.18, and 0.18 ppbv.
- Tropical tropospheric NO<sub>2</sub> columns from the CCM are biased low wrt to OMI, while tropical tropospheric O<sub>3</sub> columns tend to be biased high.
- Tropical UT O<sub>3</sub> agrees best with a 125 mole per flash LNO<sub>x</sub> source in the tropics.
- Halving (doubling) LNO<sub>x</sub> production from 250 moles per flash changes the mean tropical downward radiative flux at 163 hPa due only to ozone attributable to lightning by -43 (+63%)

# How consistent are satellite-retrieved estimates of CO?

- Time periods considered:
  - Oct15-Nov 14, 2006 (El Nino)
  - Oct15-Nov 15, 2007 (La Nina)

Altitudes considered:

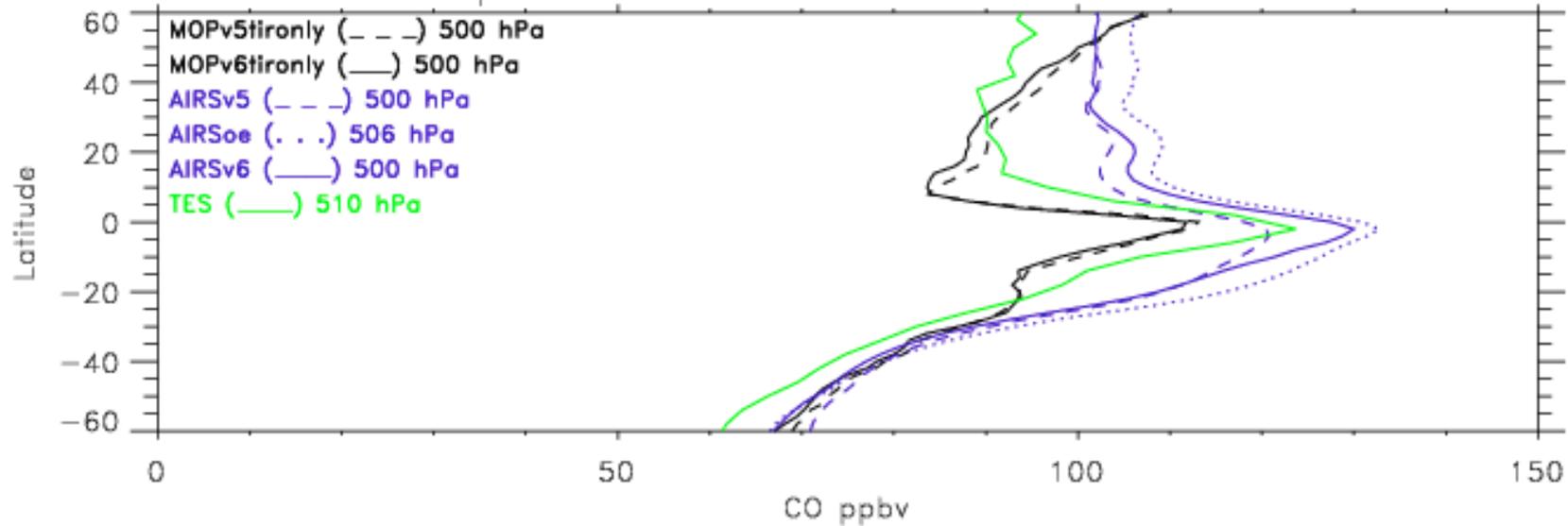
Lower (~850 hPa), middle (~500 hPa), and upper (~250 hPa) troposphere

- Compare zonal average profiles during 2006 and 2007
- Compare surface plots during 2006
- Compare El Nino – La Nina differences
- How correlated are 2006-2007 changes between the various products?

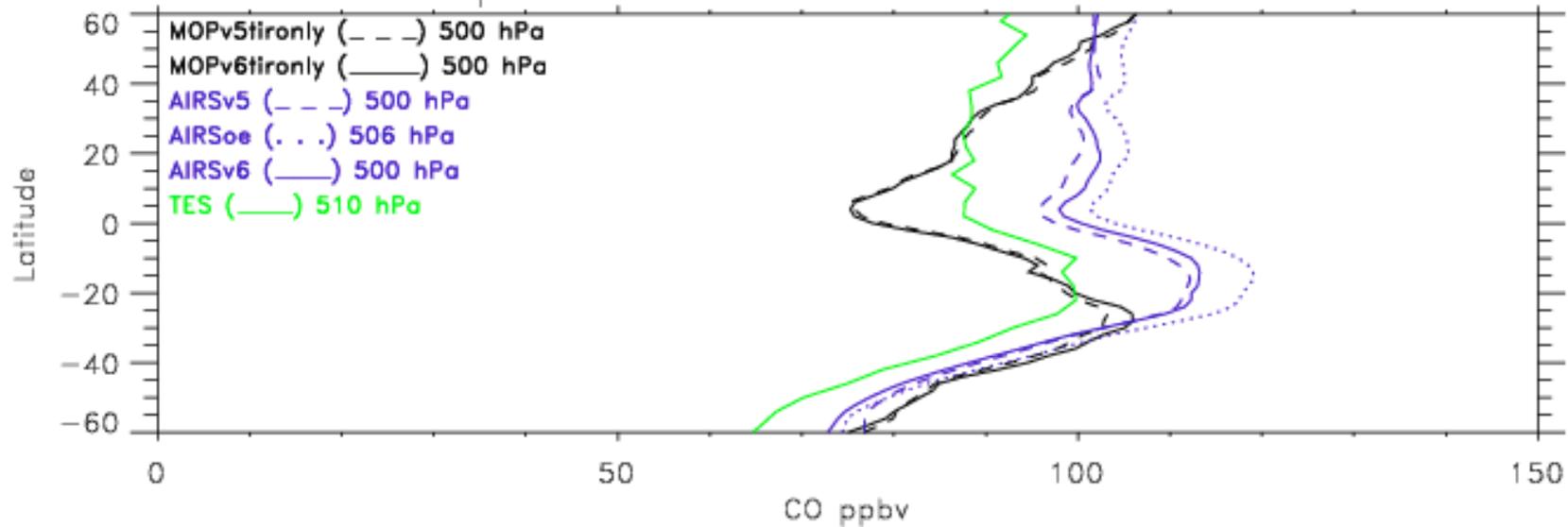
# CO products considered

- MOPITT CO (H. Worden et al., 2010; Deeter et al., 2011, 2013)
- V5 (V6) product uses NCEP (higher resolution MERRA) met fds
- V5 (V6) product a priori based on MOZART 1997-2004 (CAM-CHEM 2000-2009)
- TIRNIR products takes advantage of TIR mid-tropospheric sensitivity and NIR total column sensitivity
  
- AIRS CO (Warner et al., 2010; McMillan et al., 2011)
- V6 product uses updated a priori (monthly climatology)
- AIRSoe product is based on V5 but uses optimal estimation
  
- TES v005 CO (Ho et al., 2009; Herman and Osterman, 2012)
  
- MLS v3.3 CO (Livesey et al., 2011)

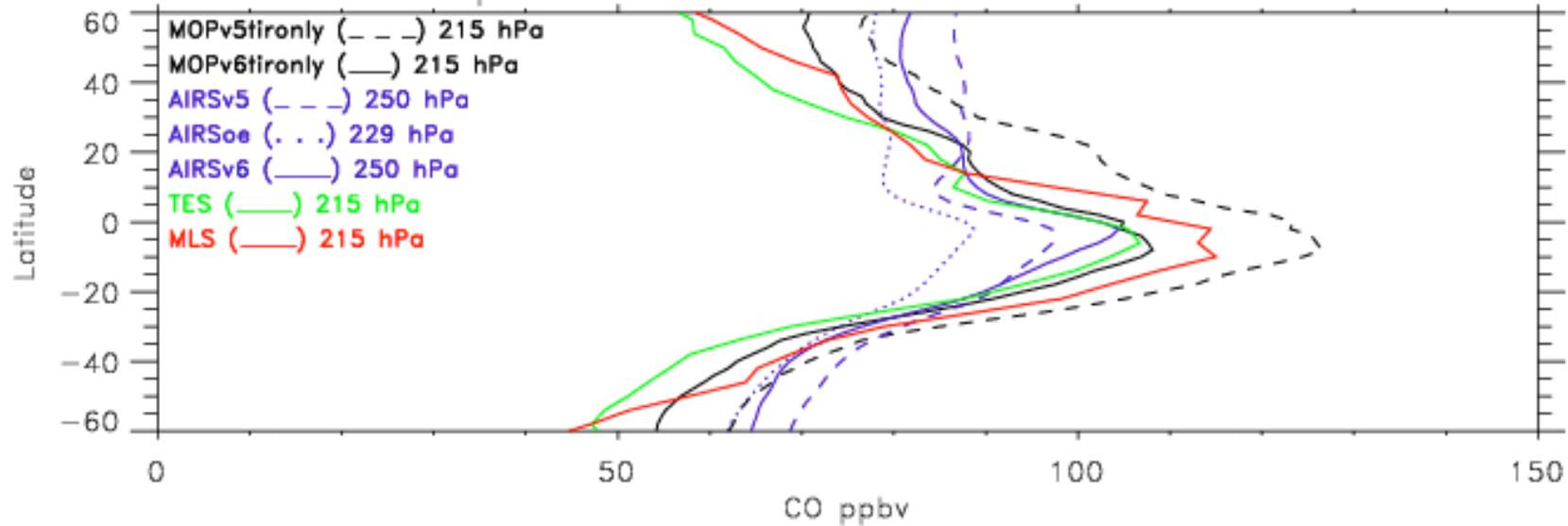
MtropCO 20061015-20061114 -180E to 180E



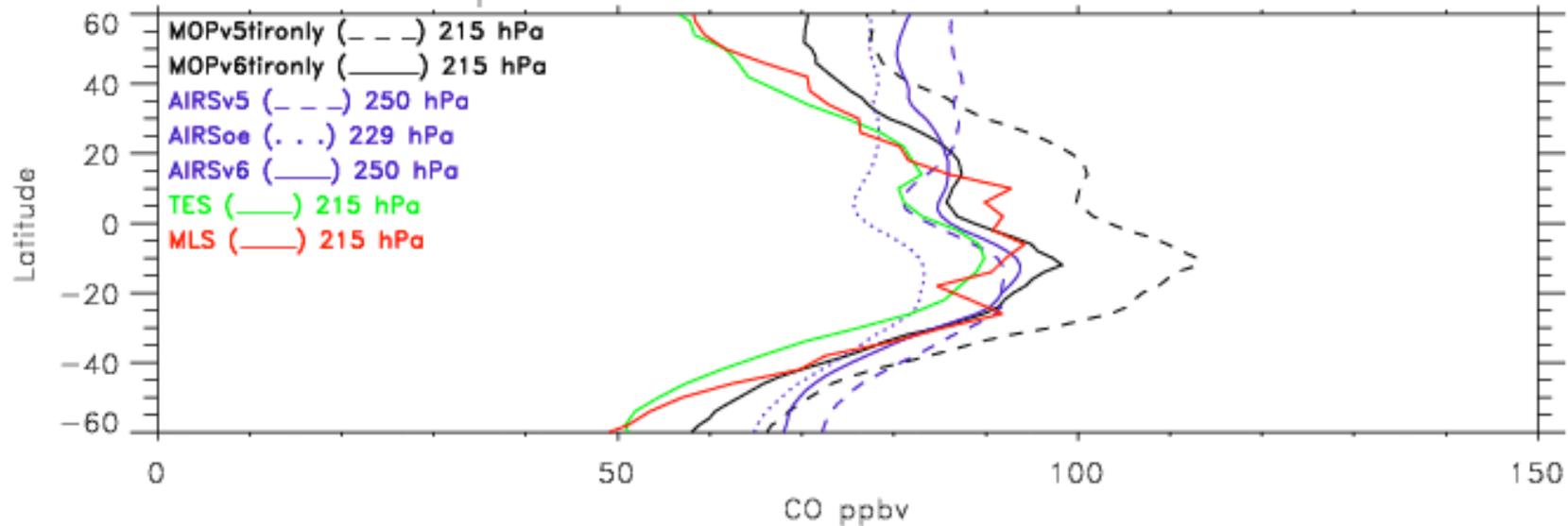
MtropCO 20071015-20071114 -180E to 180E



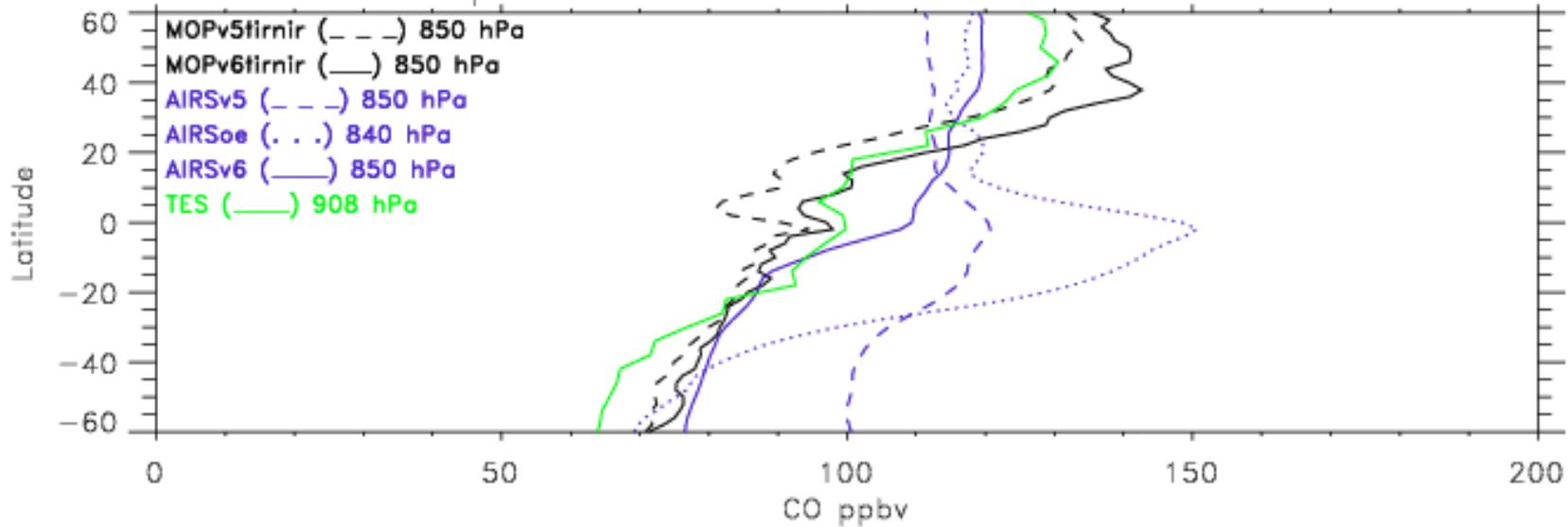
UtropCO 20061015-20061114 -180E to 180E



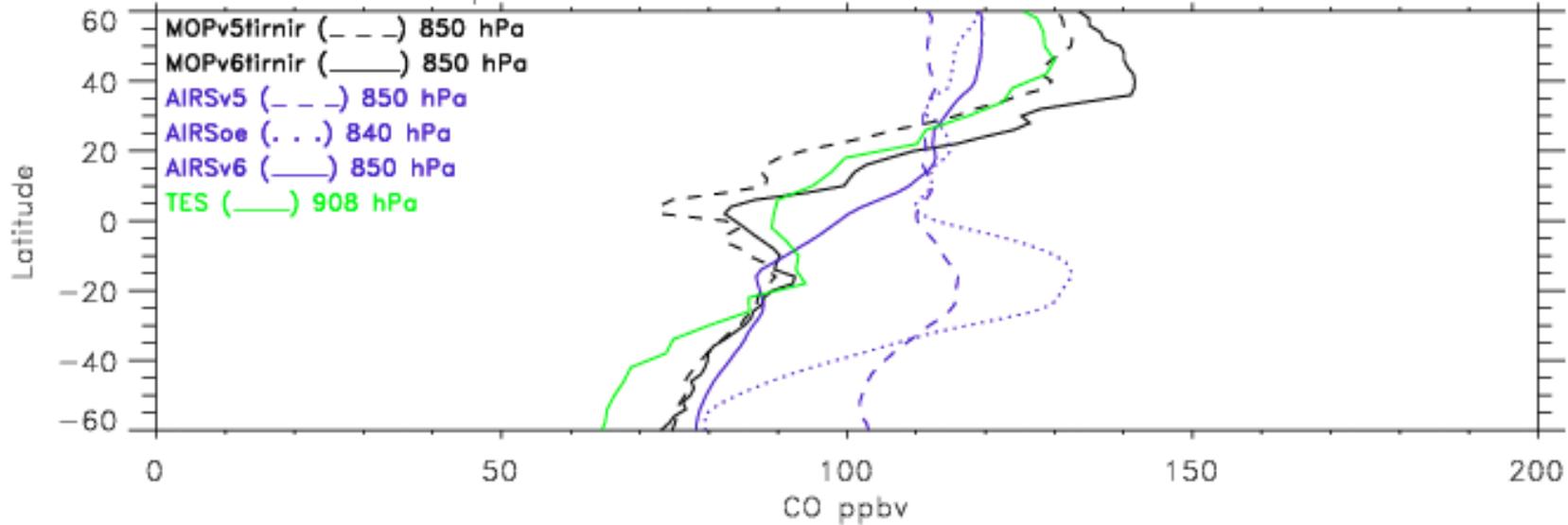
UtropCO 20071015-20071114 -180E to 180E



LtropCO 20061015-20061114 -180E to 180E



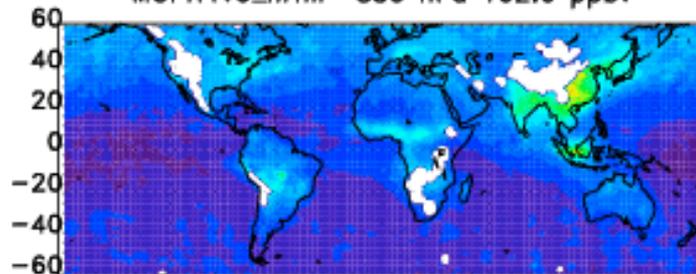
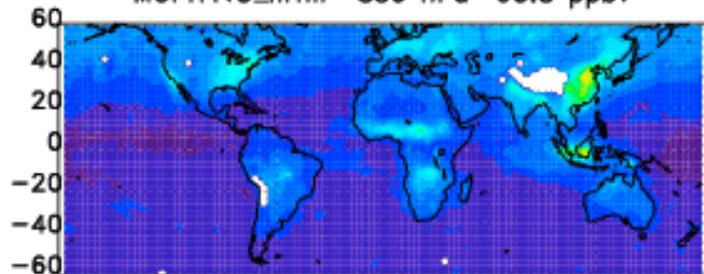
LtropCO 20071015-20071114 -180E to 180E



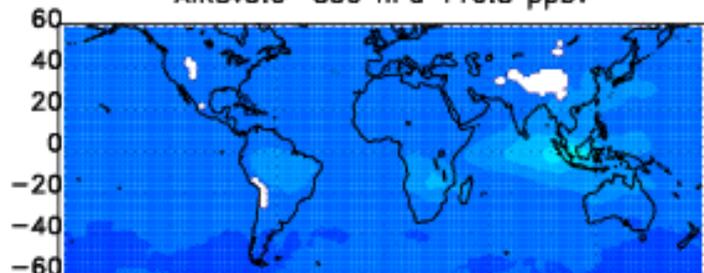
# LtropCO 20061015-20061114

MOPITTv5\_tirnir 850 hPa 95.8 ppbv

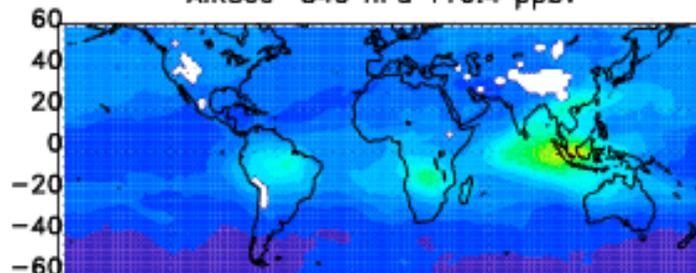
MOPITTv6\_tirnir 850 hPa 102.0 ppbv



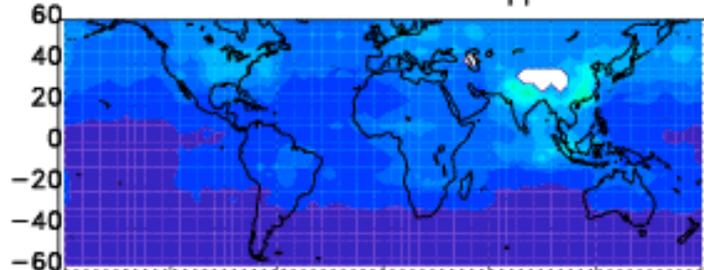
AIRsv5.0 850 hPa 110.8 ppbv



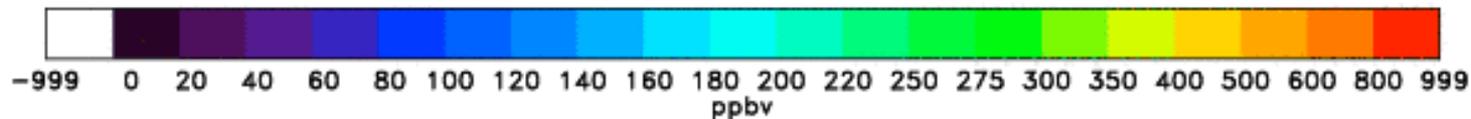
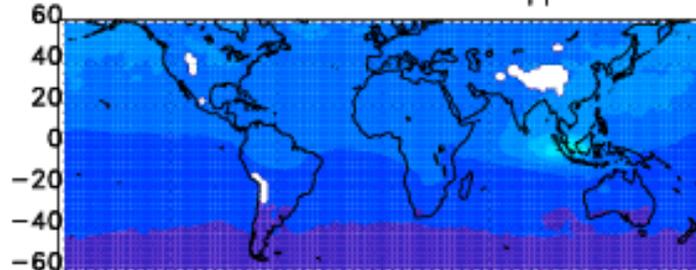
AIRSoe 840 hPa 116.4 ppbv



TESv5 908 hPa 97.2 ppbv



AIRsv6.0 850 hPa 100.6 ppbv

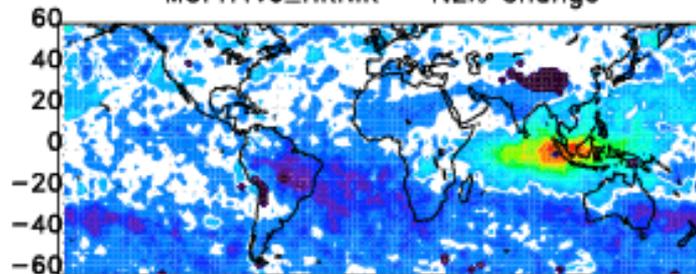
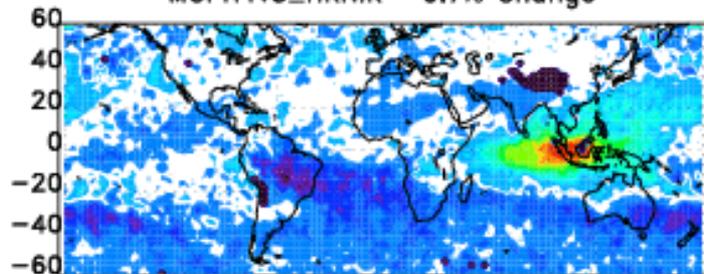


MOPITT & AIRS (2x2.5 degrees); TES & MLS (4x5 degrees)

# MtropCO:Nino(06)-Nina(07) Oct15-Nov14

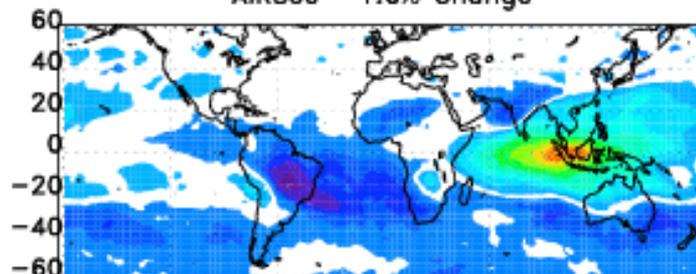
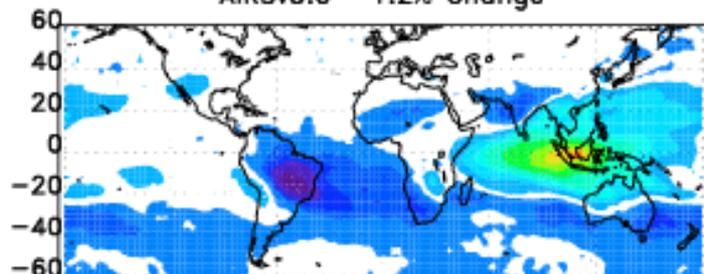
MOPITTv5\_TIRNIR 0.7% Change

MOPITTv6\_TIRNIR -1.2% Change



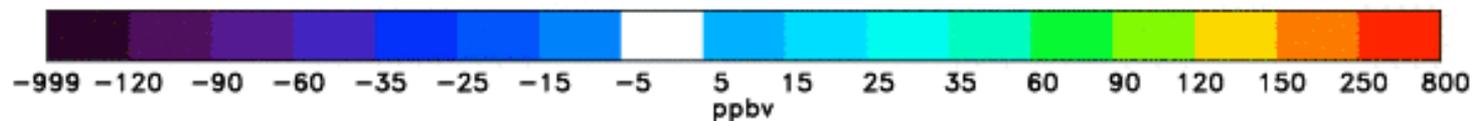
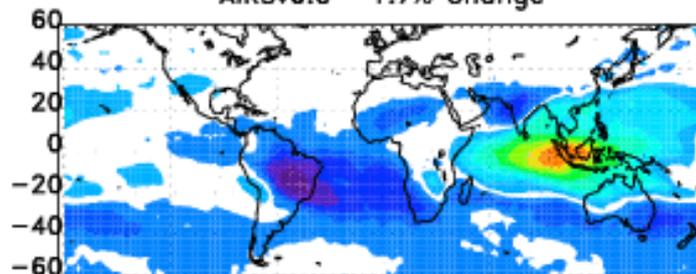
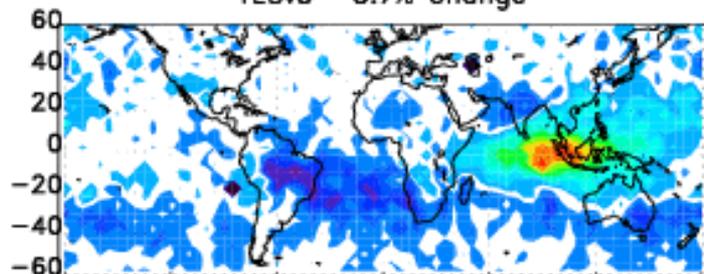
AIRsv5.0 1.2% Change

AIRSoe 1.6% Change



TESv5 3.7% Change

AIRsv6.0 1.7% Change



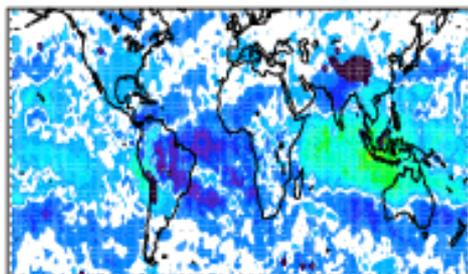
2x2.5MOPITT 500 hPa 2x2.5AIRsv5 500 hPa 2x2.5AIRSoe 506 hPa 4x5TESv5 510 hPa 2x2.5AIRsv6 500 hPa

# UtropCO:Nino(06)-Nina(07) Oct15-Nov14

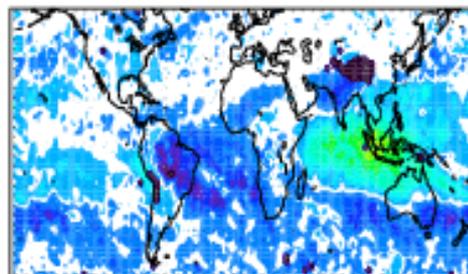
MOPITTv5\_TIRNIR 3.1% Change

MOPITTv6\_TIRNIR 2.2% Change

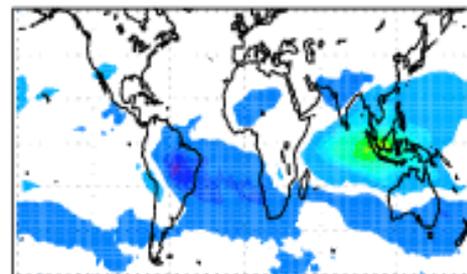
AIRsv5.0 0.6% Change



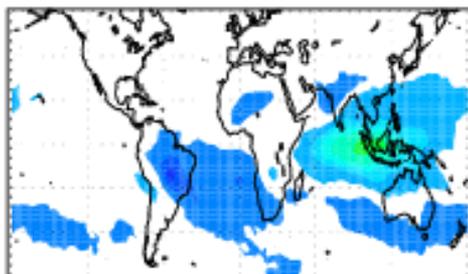
AIRSoe 0.8% Change



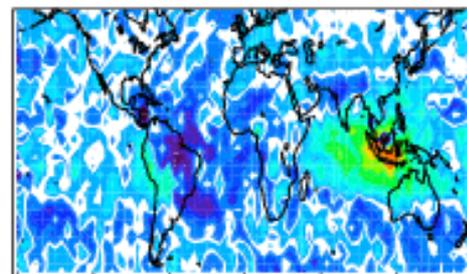
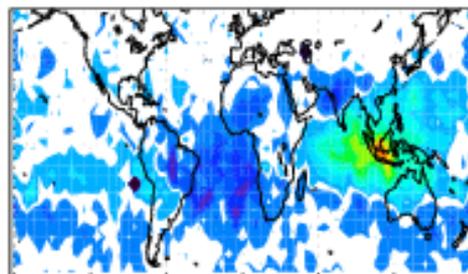
TESv5 4.1% Change



MLsv3 7.4% Change



AIRsv6 1.1% Change



-999 -120 -90 -60 -35 -25 -15 -5 5 15 25 35 60 90 120 150 250 800

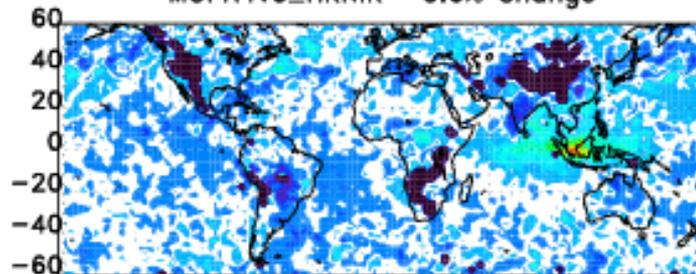
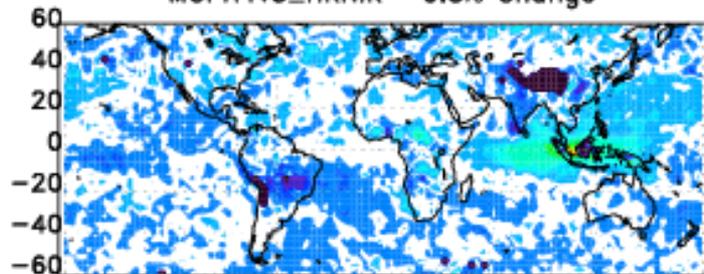
ppbv

2x2.5MOPITT 215 hPa 2x2.5AIRsv5 250 hPa 2x2.5AIRSoe 229 hPa 4x5TESv5 215 hPa 4x5MLsv3 215 hPa

# LtropCO:Nino(06)-Nina(07) Oct15-Nov14

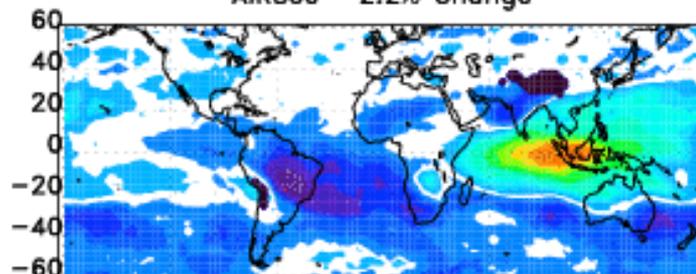
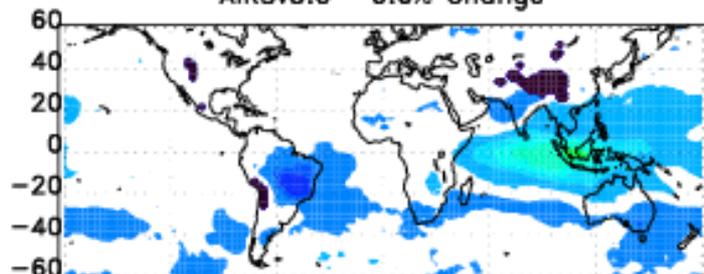
MOPITTv5\_TIRNIR 0.3% Change

MOPITTv6\_TIRNIR 0.6% Change



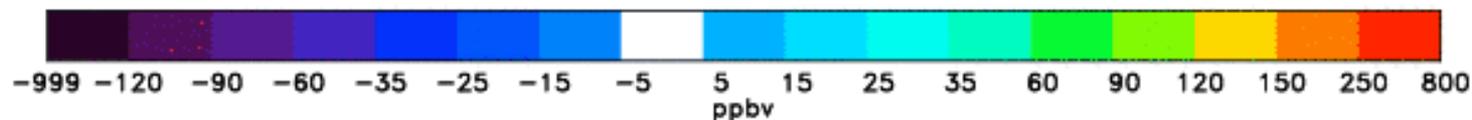
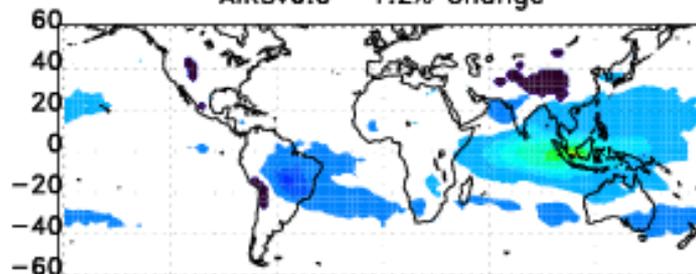
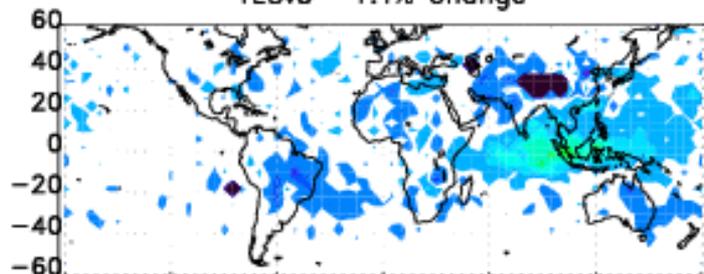
AIRsv5.0 0.6% Change

AIRSoe 2.2% Change



TESv5 1.1% Change

AIRsv6.0 1.2% Change



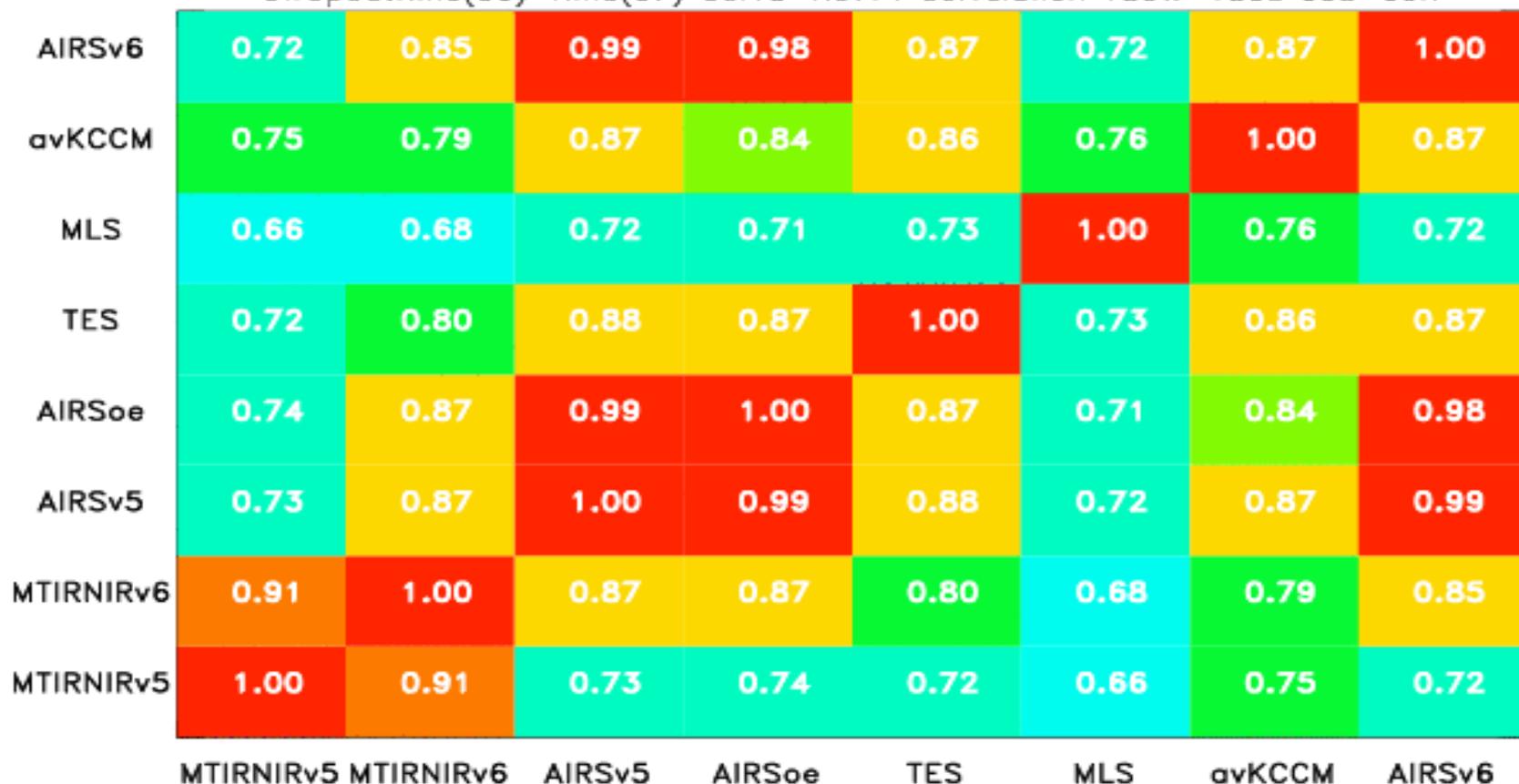
2x2.5MOPITT 850 hPa   2x2.5AIRsv5 850 hPa   2x2.5AIRSoe 840 hPa   4x5TESv5 908 hPa   2x2.5AIRsv6 850 hPa

MtropCO:Nino(06)-Nina(07) Oct15-Nov14 Correlation 180W-180E 60S-60N



\*\*\*\*    \*\*\*\*    0.00    0.30    0.35    0.40    0.45    0.50    0.55    0.60    0.65    0.70    0.75    0.80    0.85    0.90    0.95    1.00  
 Correlation coefficient

UtropCO:Nino(06)-Nina(07) Oct15-Nov14 Correlation 180W-180E 60S-60N



\*\*\*\* \*\*\*\* 0.00 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00  
Correlation coefficient

LtropCO:Nino(06)-Nino(07) Oct15-Nov14 Correlation 180W-180E 60S-60N



\*\*\*\*    \*\*\*\*    0.00   0.30   0.35   0.40   0.45   0.50   0.55   0.60   0.65   0.70   0.75   0.80   0.85   0.90   0.95   1.00  
 Correlation coefficient

LtropCO:Nino(06)-Nina(07) Oct15-Nov14 Correlation 180W-180E 60S-60N



\*\*\*\*    \*\*\*\*    0.00    0.30    0.35    0.40    0.45    0.50    0.55    0.60    0.65    0.70    0.75    0.80    0.85    0.90    0.95    1.00  
 Correlation coefficient

## Summary of CO comparison

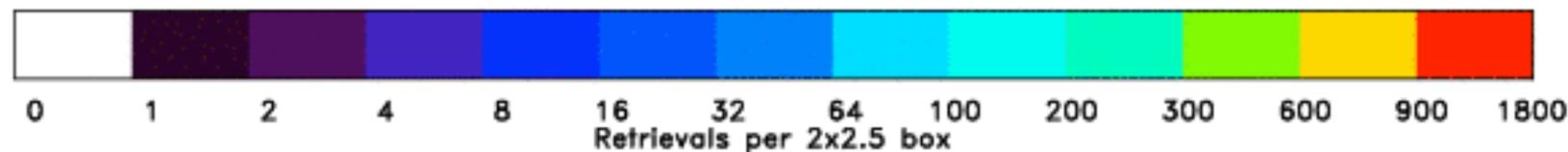
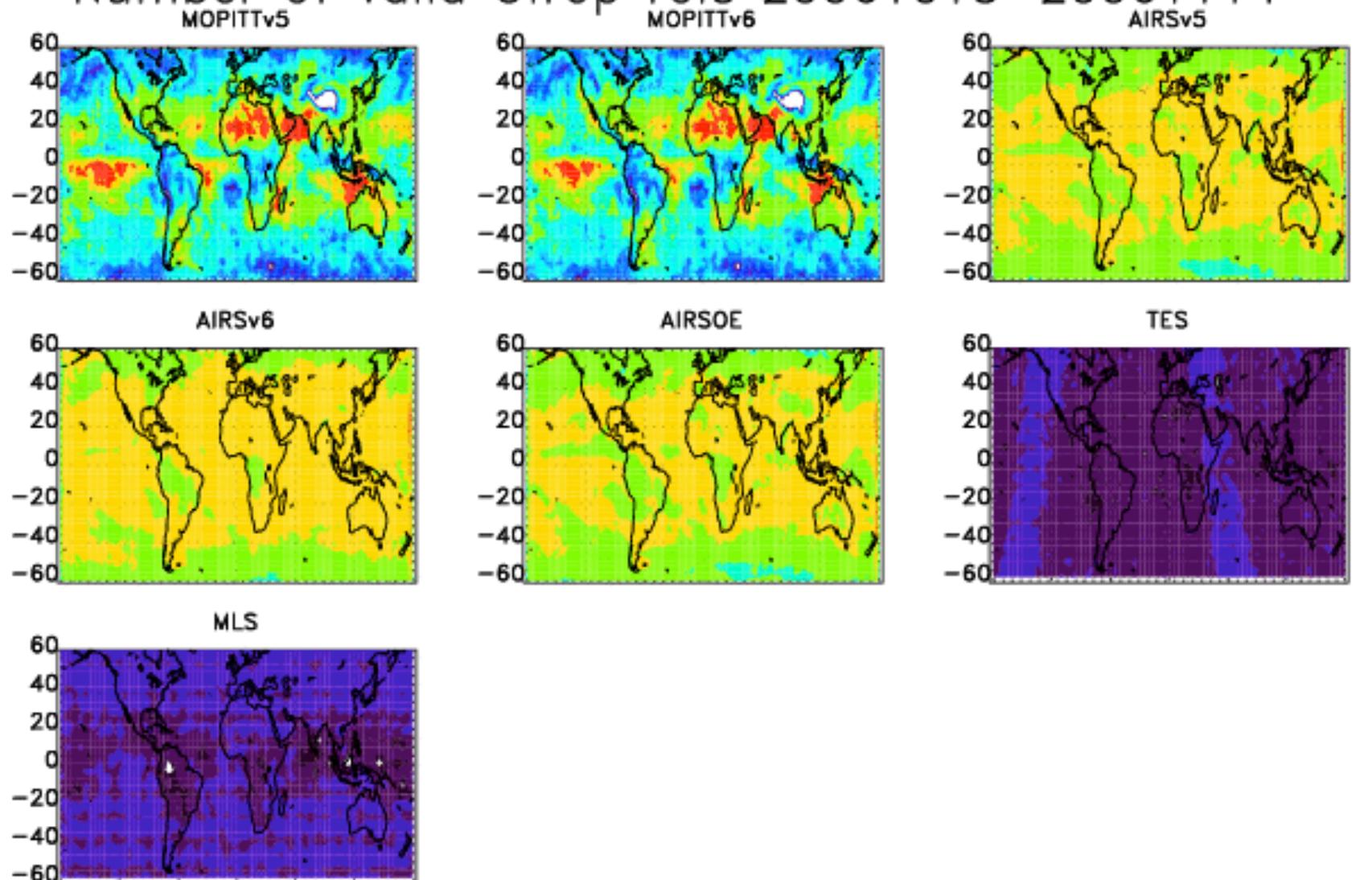
- **Midtroposphere**
- Strong Indonesian (Brazilian) fire signal in 2006 (2007)
- AIRS products have high bias wrt MOPITT
- MOPITT product shows pronounced minimum in northern subtropics
- Products are similar south of 20°S
- TES has low-bias in extratropics wrt MOPITT/TES
- **Upper troposphere**
- All products show peak in tropics with peak values varying by ~50%
- MOPITT v5 product (esp TIRNIR) has high-bias (v6 much better)
- AIRS products have tropical low-bias wrt MOPITT.
- **Lower troposphere**
- AIRSv5 and AIRSoe products biased high in SH (a priori)
- Fire signal is most prominent in AIRSoe product
- Anthropogenic signal seen in MOPITT and to a lesser degree TES products
- CO amounts change substantially between AIRS & MOPITT versions

## Summary of 2006-2007 correlations plots

- AIRS-based estimate of 2006-2007 change does not depend on AIRS version ( $R > 0.95$  between AIRS products at all altitudes)
- MOPITT-based estimate of 2006-2007 change does depend on version of TIRNIR product. ( $R=0.62$  between V5 & V6 in lower troposphere). V6 product likely better.
- Inter-satellite correlations of 2006-2007 changes are 0.85-0.95 in MT, 0.70-0.85 in UT, and 0.50-0.75 in LT
- Correlations between UT MLS CO and UT AIRS/MOPITT CO (0.66-0.76) are lower than correlations between UT TES CO and UT AIRS/MOPITT CO (0.72-0.88).
- In lower troposphere, correlation between TIRNIR-retrieved changes and changes from other products are relatively low (this is a good thing).

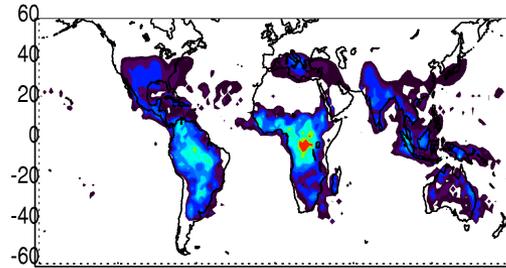
# Extra Slides

# Number of valid Utrop rets 20061015–20061114

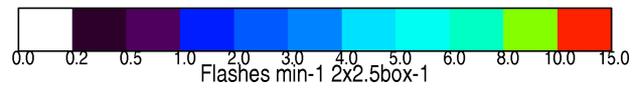
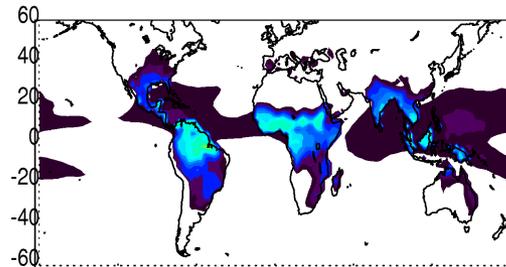


# Mean flash rate 20070901-20071130

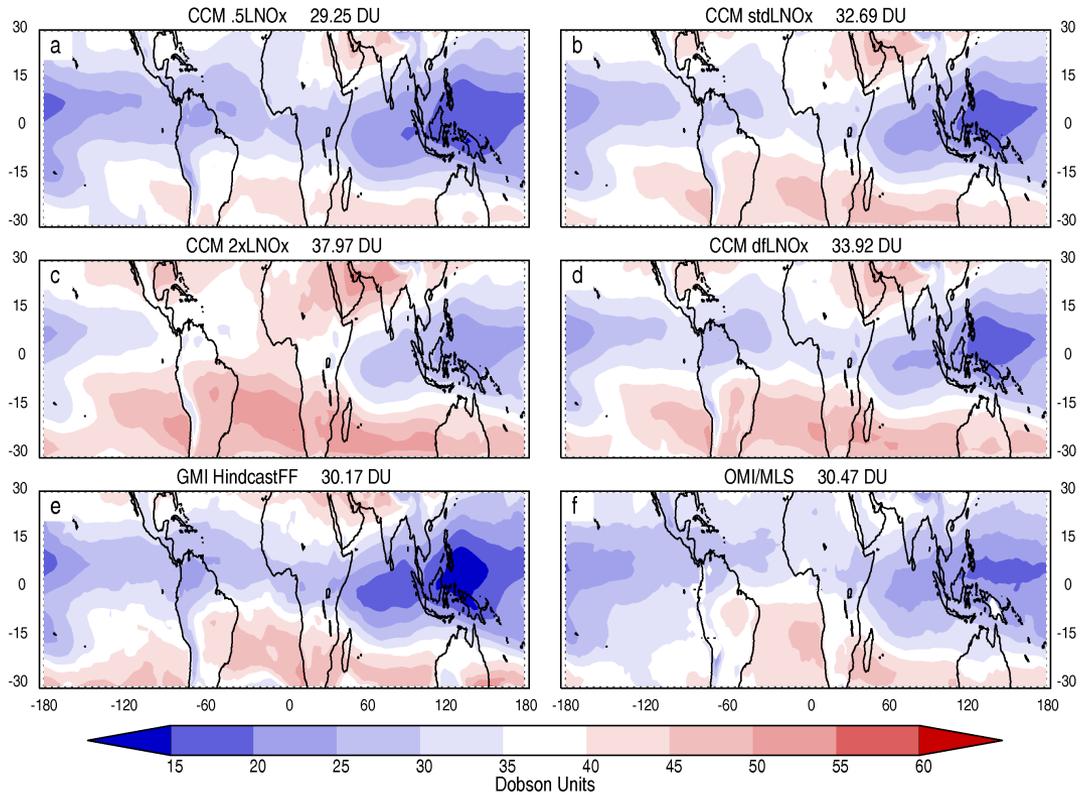
v2.3 OTDLISs 49.3 F s-1



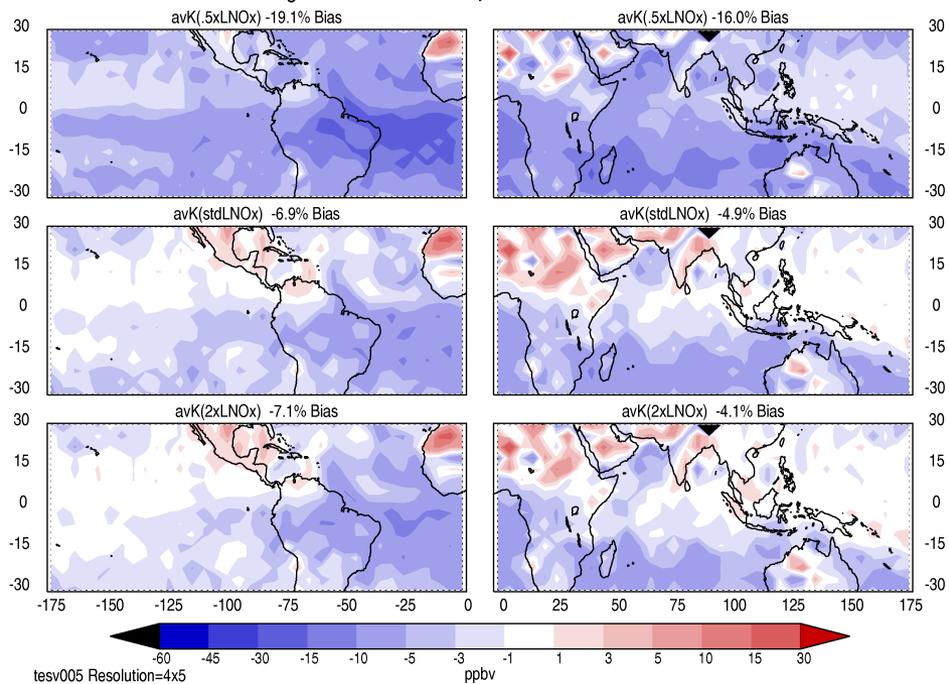
CCM 47.6 F s-1



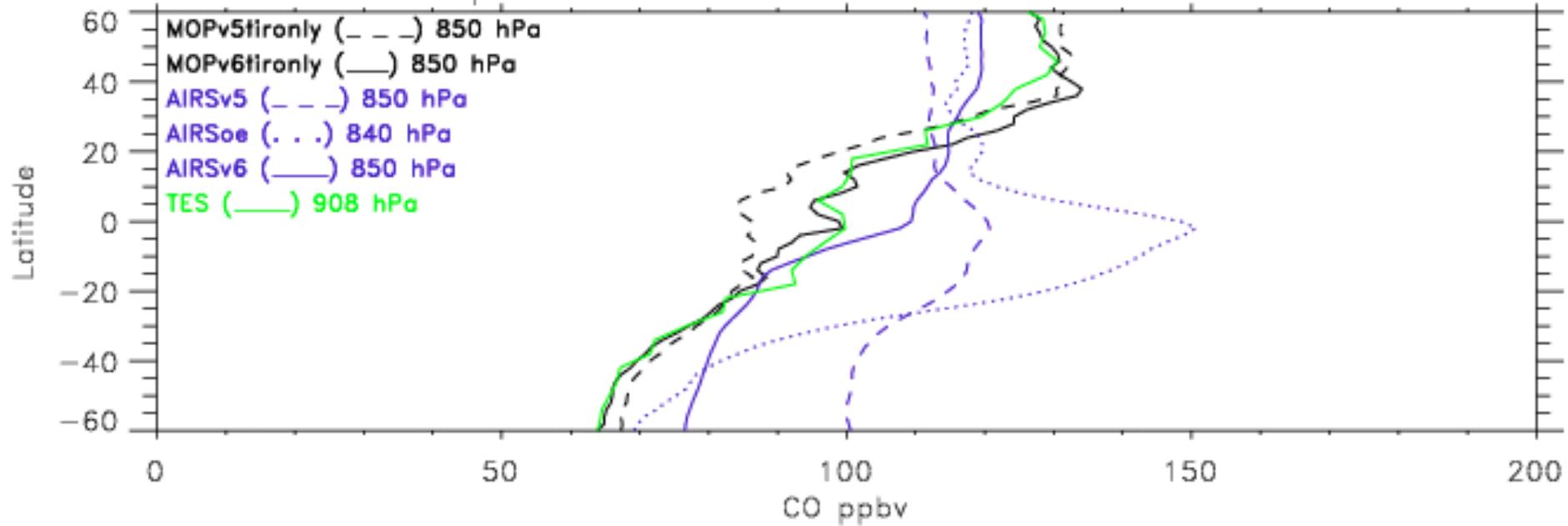
# NASA-GSFC CCM, GMI Hindcast and OMI/MLS TCO



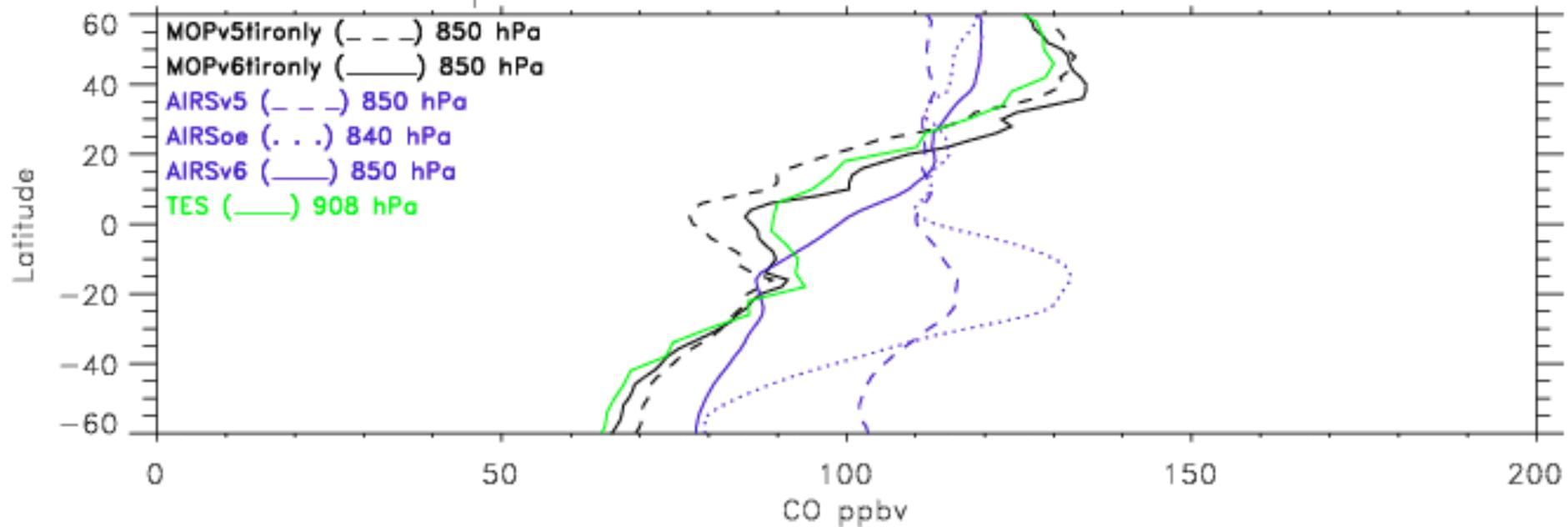
(ii) Mean O<sub>3</sub> Bias with Respect to TES at 825 hPa



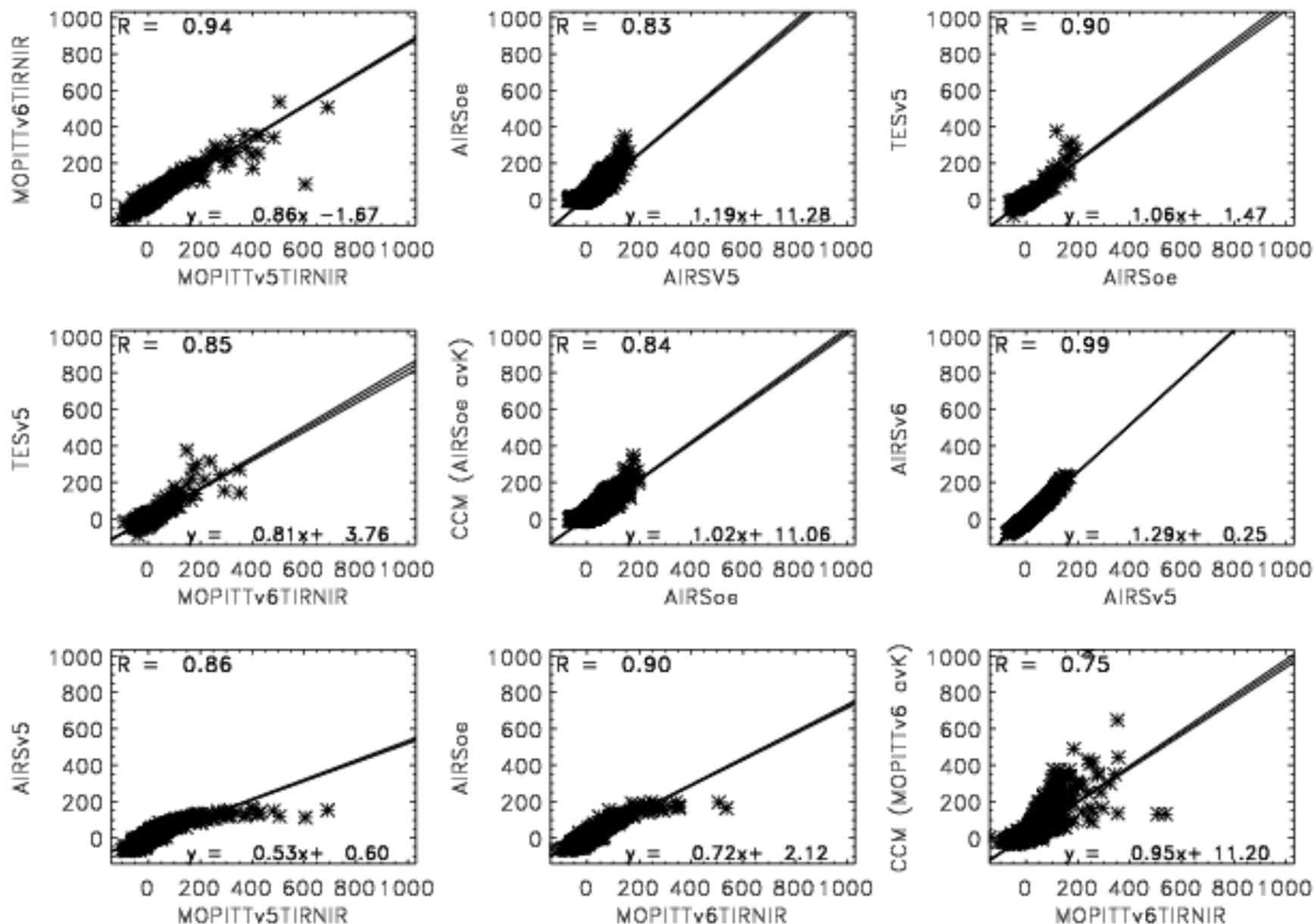
LtropCO 20061015-20061114 -180E to 180E



LtropCO 20071015-20071114 -180E to 180E

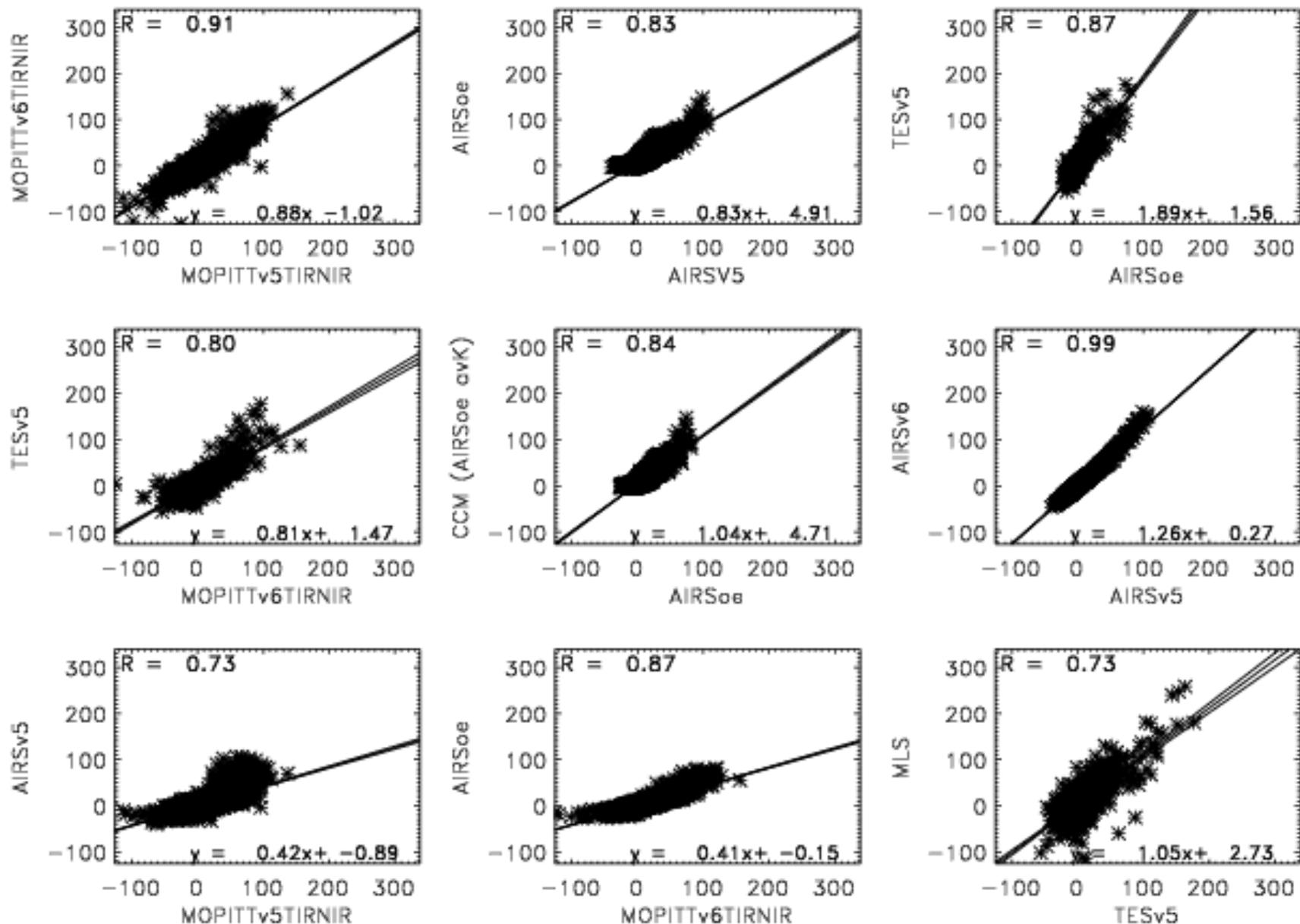


# MtropCO:Nino(06)-Nina(07) Oct15-Nov14

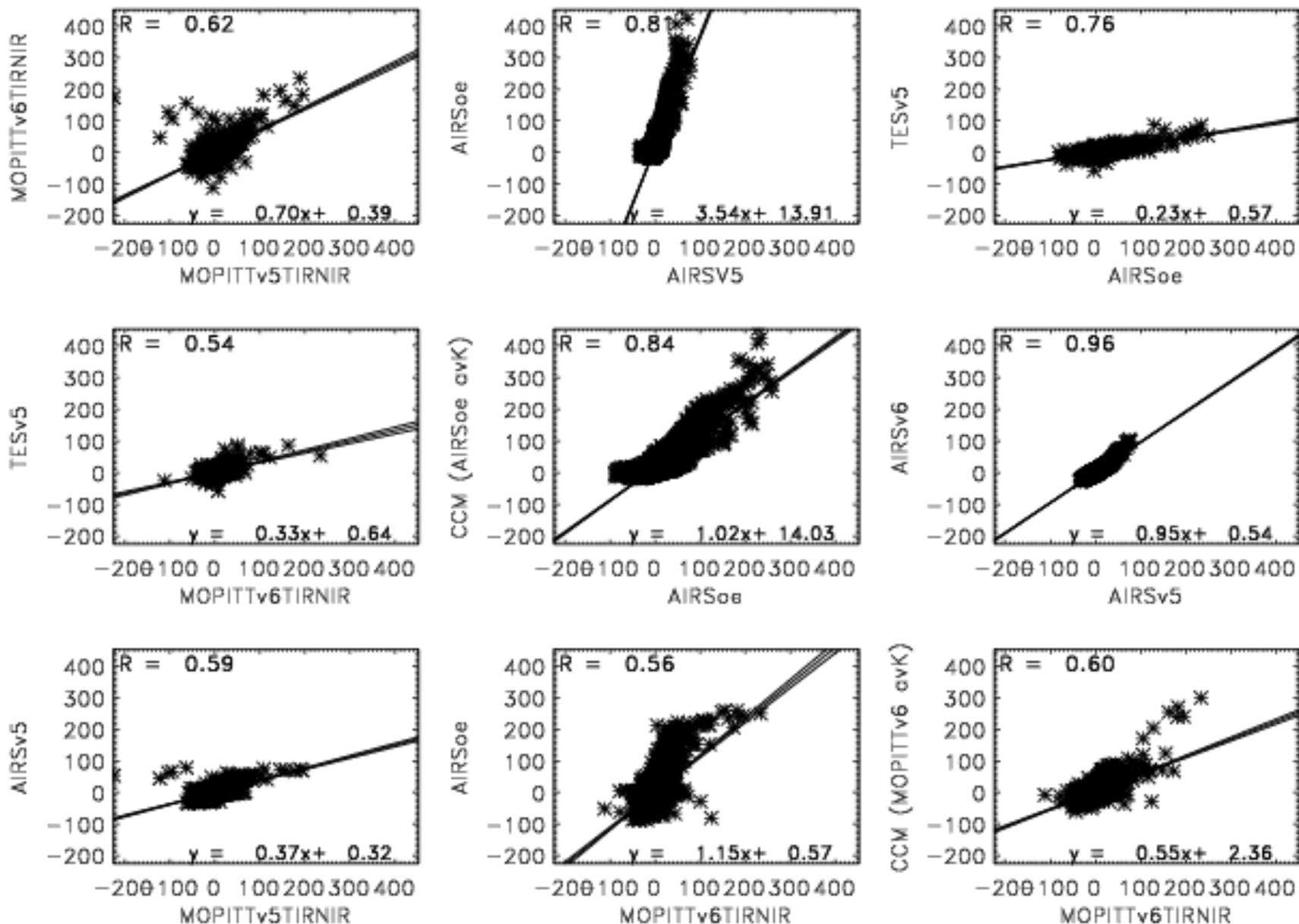


2x2.5MOPITT 500 hPa 2x2.5AIRSV5 500 hPa 2x2.5AIRSoe 506 hPa 4x5TESv5 510 hPa 2x2.5AIRSV6 500 hPa 180W-180E 60S-60N

# UtropCO:Nino(06)–Nina(07) Oct15–Nov14



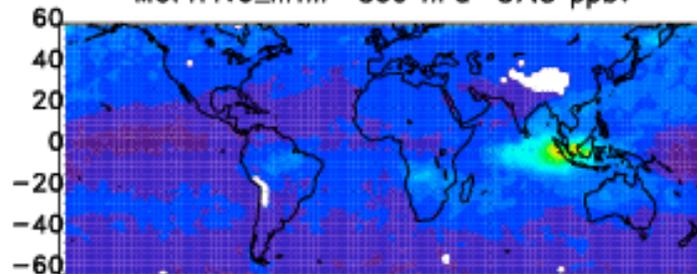
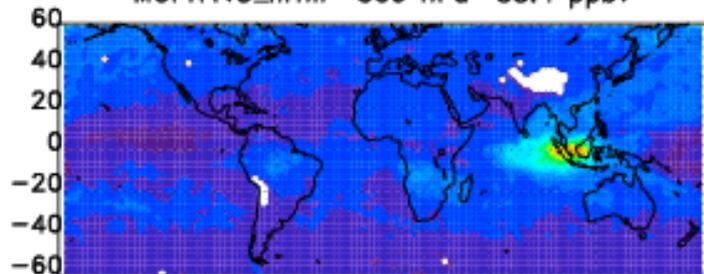
# LtropCO:Nino(06)-Nina(07) Oct15-Nov14



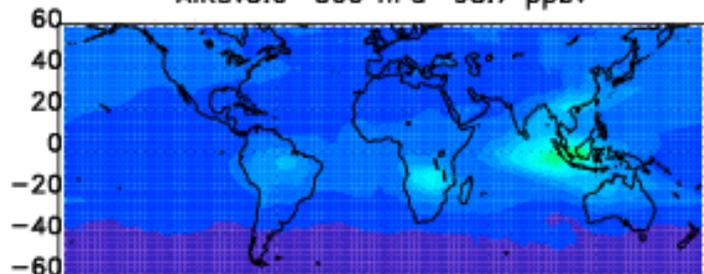
# MtropCO 20061015-20061114

MOPITTv5\_tirnir 500 hPa 88.4 ppbv

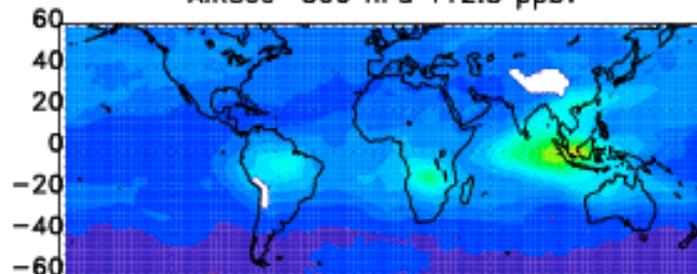
MOPITTv6\_tirnir 500 hPa 87.8 ppbv



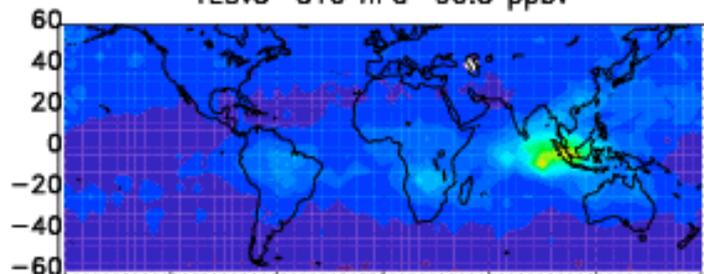
AIRsv5.0 500 hPa 98.7 ppbv



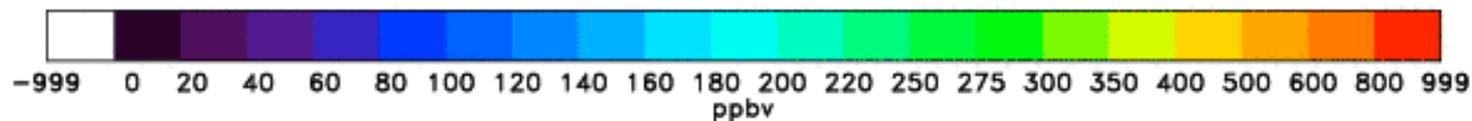
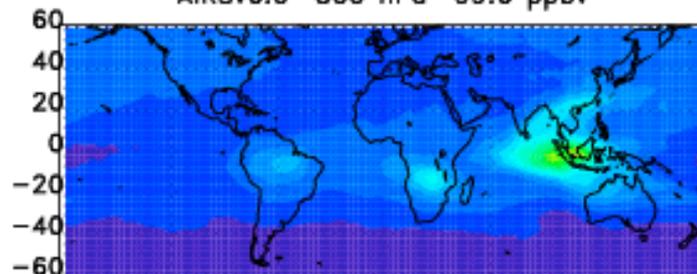
AIRSoe 506 hPa 112.8 ppbv



TESv5 510 hPa 90.5 ppbv

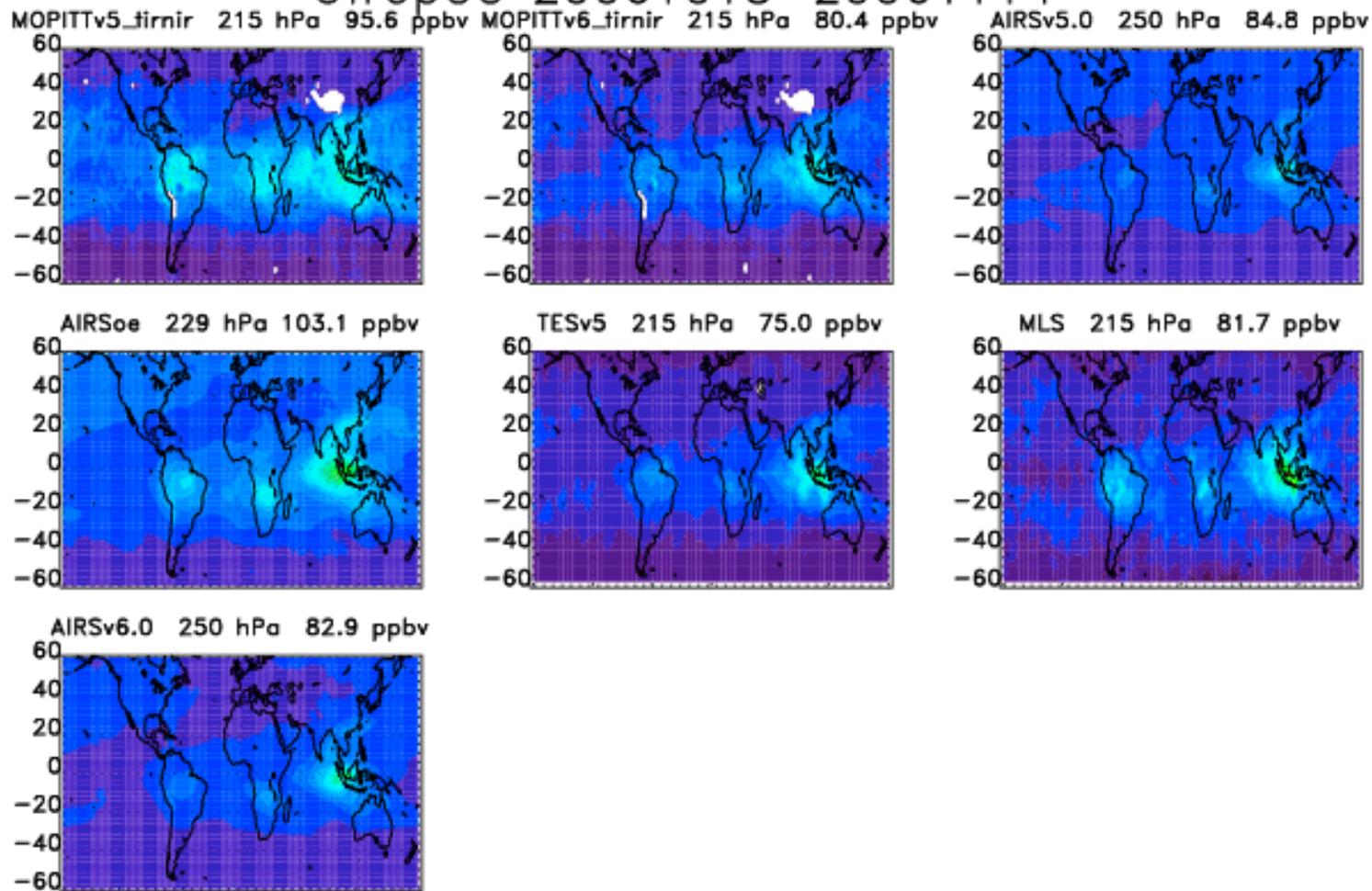


AIRsv6.0 500 hPa 99.6 ppbv



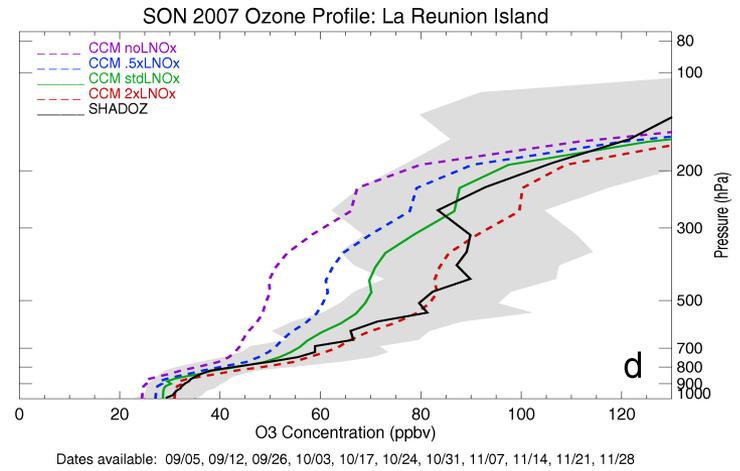
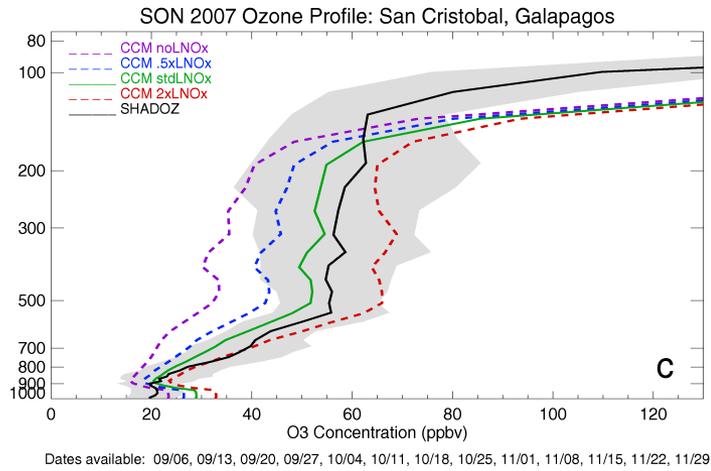
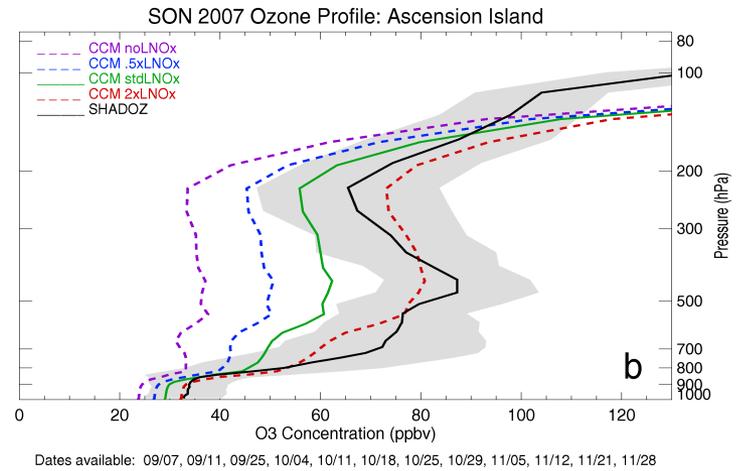
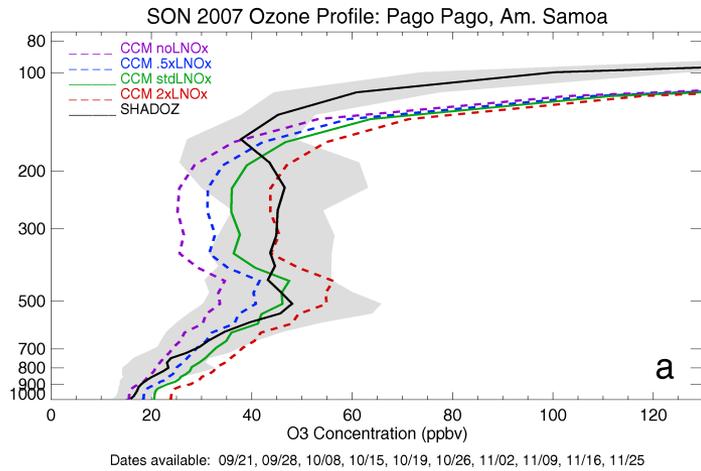
MOPITT & AIRS (2x2.5 degrees); TES & MLS (4x5 degrees)

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-999 0 20 40 60 80 100 120 140 160 180 200 220 250 275 300 350 400 500 600 800 999  
ppbv

MOPITT & AIRS (2x2.5 degrees); TES & MLS (4x5 degrees)



SHADOZ ozone (Thompson et al., 2012)